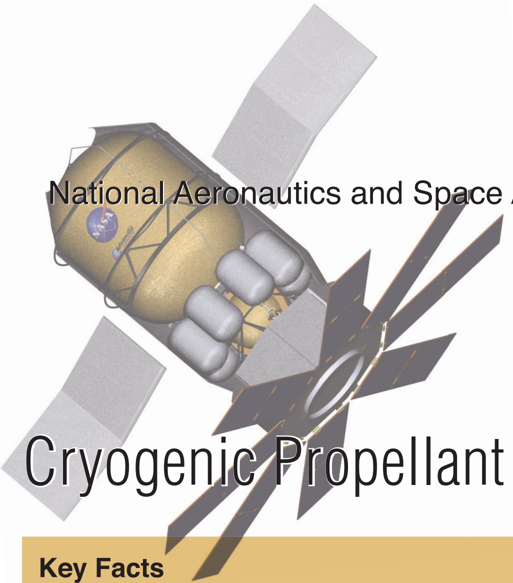
National Aeronautics and Space Administration



NASA **facts**

Cryogenic Propellant Storage and Transfer Project

Key Facts

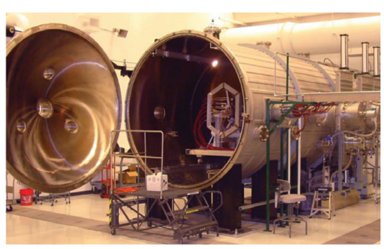
- NASA is laying the groundwork to enable humans to safely reach multiple destinations, including asteroids, Lagrange points, the Moon, and Mars.
- Under the Technology Demonstration Mission (TDM) Program, the Cryogenic Propellant Storage and Transfer (CPST) Project will demonstrate the in-space capability of long-term storage and transfer of cryogenic propellants (liquid hydrogen), essential for transportation on deep-space exploration missions.
- CPST technologies are considered a high priority for NASA and have been further identified in the National Academies' Space Technology Roadmap as a critical capability.
- The goals of the CPST Project are to advance technologies that will enable the establishment of commercial capability for a reliable cryogenic fluid system (CFS).

The Challenge

Cryogenic propellants—gasses chilled to subfreezing temperatures and condensed to form highly combustible liquids—provide high-energy propulsion solutions critical to future, long-term human exploration missions beyond low-Earth orbit (LEO). The challenge is to develop a means of storing and transferring these propellants in space for long-duration missions, and preventing temperature fluctuations that contribute to fuel losses due to boil-off—vaporization of a liquid due to heating.

Future Mission Needs

A cryogenic propulsion stage (CPS) and propellant depots both require the long-term storage and transfer of cryogenic propellants. The primary function of a CPS is to provide a large amount of energy to enable vehicles to travel between destinations in space. Near-term missions are slated for 5 to 10 days and future missions will require many months. Propellant depots will require storage durations in excess of 1 year, and will loiter in LEO. All missions requiring the storage of cryogenic propellants for more than a couple of hours will need to accurately monitor the temperature, pressure, and mass of the propellant remaining in the tank.



Key Agency facilities used by CPST. ➤

Technology Maturation

Capabilities for future extended duration missions in space have been identified as necessary to effectively transfer propellant in microgravity and to reduce cryogenic propellant boil-off. The CPST Project decomposed these capabilities which were developed, tested, and analyzed. The Project's technology maturation activities have been completed and a suite of technologies has been selected for flight demonstration. The technology maturation efforts are described below.

Long-Term Storage

The thermal control system is comprised of passive and/or active systems. It is required for long-duration missions in space to protect the CFS from excessive temperature fluctuations while in orbit.

- Passive thermal control includes the combination of insulation, low-conductivity structure, mixing, and thermodynamic venting.
  - A protective blanket must be thick (>50 radiation shield layers resulting in 2 to 3 inches) for long-duration missions in space. This effort characterized the impact on blanket performance of various approaches to optimize the interface between the multilayer insulation (MLI) blanket and elements that must penetrate it such as structure and plumbing.
- Active thermal control requires refrigeration by the integration of a cryocooler with the tank system.
  - CPST integrated a cryocooler with a propellant tank using a cooled gas distribution loop to demonstrate the thermal and structural feasibility of hydrogen reduced boil-off. The tubing containing the circulating cold gas is thermally linked to the tank structure, plumbing, and wires to intercept conductive heat loads. In addition, Broad Area Cooling (a distributed cooling scheme) was inserted in the middle layers of the MLI to intercept radiative heat loads. This reduces the heat that reaches the propellant.

MLI penetration heat leak study (left), liquid hydrogen active cooling thermal test (center), and vibration acoustic test article (right).

Fluid Transfer

- Liquid acquisition uses capillary forces to enable movement of liquid along the surface of a solid, such as a paper towel absorbing liquid.
  - Outflow through a screen channel liquid acquisition device (LAD) was investigated. The capillary forces in the small pores of the screen are used to separate liquid from vapor in microgravity prior to transfer. CPST investigations showed that finer mesh screens provided adequate flow rates.
- Line chilldown eliminates phase change (bubble formation) in a propellant transfer line by prechilling the piping and valves.
  - CPST demonstrated a method that enables continuous chilling to avoid bubble formation.

Propellant Gauging

CPST is developing a low-gravity, radiofrequency, mass gauge to understand limitations of gauging at low thrust. The Project is also developing a software tool for rapidly assessing the amount of available liquid propellant.

Radiofrequency mass gauging.

Design and Manufacturing Pathfinder

Cryogenic fluid management subsystems were selected to demonstrate fast-paced design and manufacturing techniques for the flight cryogenic fluids system.

Technology Demonstration Mission

Flight Demonstration

The most promising technologies that emerged from the maturation efforts will be integrated into a small, but scalable, cryogenic fluid system, and then flown in space. A series of cryogenic propellant storage, transfer, and mass gauging demonstrations will be performed in orbit over an extended duration. This mission will demonstrate performance of these technologies in a microgravity environment yielding data crucial for the validation of the predictive performance models and the subsequent designs of much larger, in-space cryogenic systems. This demonstration is critical to enable future missions in space.

Modeling

A suite of models capable of predicting the performance of an integrated cryogenic fluid system will be developed. Initially, technology maturation data, as well as data from cryogenic fluid experiments predating this mission, will be used to develop and refine the predictive performance models. Post mission, CPST flight demonstration data and any complementary ground demonstration data will be used to further refine and validate the models. The validated predictive performance models will be used in the design of future cryogenic fluid systems for future missions in space.

Public Participation and Reviews

Technology Workshops

The results of the technology maturation efforts will be shared, in detail, with industry at workshops at NASA Glenn Research Center in the summer and fall of 2013.

Flight Mission Reports

The results of the CPST flight mission will be published and shared with industry in 2018.

Website

http://www.nasa.gov/mission_pages/tdm/cpst/index.html

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